Journal of Science Education and Technology, Vol. 14, Nos. 5/6, December 2005 (© 2005)
DOI: 10.1007/s10956-005-0220-4

Awareness of Societal Issues Among High School Biology Teachers Teaching Genetics

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The purpose of this study was to investigate how aware high school biology teachers are of societal issues (values, moral, ethic, and legal issues) while teaching genetics, genetics engineering, molecular genetics, human heredity, and evolution. The study includes a short historical review of World War II atrocities during the Holocaust when scientists from all the above-mentioned disciplines had been involved in trying to support and develop the eugenics theories. It investigates pre- and postwar theories of the eugenics movement in the United States which were implemented successfully in Germany and a literature survey of the studies of societal issues related to these subjects. The sample consisted of 30 male and female biology teachers. Enclosed are teachers' answers in favor or against including debates about societal issues in their classrooms while teaching the disciplines mentioned above. Teachers' answers were analyzed in relation to three variables: years of teaching experience, gender, and religion faith. Data were collected from questionnaires and personal interviews and analyzed according to qualitative and quantitative methods. The results show that amongst the teachers there is a medium to low level of awareness of societal issues, while mainly emphasizing scientific subjects in preparation of matriculation examinations. The majority of the teachers do not include societal issues in their teaching, but if students raise these issues, teachers claimed to address them. No differences in teachers' opinions to societal issues were found in relation to gender or religious faith. Teachers with more years of teaching experience tend to teach with a more Science, Technology, and Society (STS) approach than novice teachers. The results are discussed in relation to teachers' professional development and teaching strategies are suggested to be used in their classrooms based on a STS approach, which includes the societal issues as a main goal.

KEY WORDS: teaching genetics; societal issues; values moral ethics; atrocities and holocaust; eugenics theories.

Scientific–technological developments create bioethical dilemmas that affect people's day-to-day life. Progress in molecular biology and genetic engineering and most recently, the human genome mapping may have already given rise to societal issues, which include bioethical aspects, as well as social and political ones. In this paper, we use the term societal issues as was presented in the Science, Technology, and Society (STS), approach by Bybee *et al.* (1980) and developed as a forth component of a science curriculum relevant to students' needs, by Yager and Hofstein (1986). The right to preserve the confidentiality of a person's genetic information from his place of employment or insurance company, the right to abort a fetus found to have a genetic defect and the technological ability to clone fetuses, are issues which involve ethical, moral, and human values.

Scientists and educators warn of the danger of science progressing and developing without consideration of the moral implications of this new knowledge on society (Ehsasn, 1996; Lindell and Milczarek, 1997). They assume, that science teachers can be the link between the world of science

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and society, since they have an important role in educating their students to function as citizens in a scientific and technological society. The Science, Technology, and Society (STS) approach advocates science technology literacy education of every citizen in our society (Hart and Robottom, 1990; Hurd, 1986; Rosenthal and Bybee, 1988). The need to relate to ethical, moral, and human values while teaching biology has been raised by Gottlieb (1976), Bybee *et al.* (1980), and Dass (1997).

However, Gottlieb (1976) noted that "*In order to avoid political and economic repercussions, public school teachers do not relate to these issues while teaching science and tend to stay away from controversial subject matter*" and "*even on the college level, the preaching of ethics and values is primarily relegated to sociology, anthropology and philosophy courses.*" The fact that teachers avoid controversial topics in their instruction in order not to upset parents and students was mentioned by Stronk (2002). He noted that teachers lack appropriate instructional strategies and may fail to recognize the importance of motivating students by placing science in a relevant context. His suggestions are to use method courses in order to assist pie-service high school teachers in using an instructional strategy, which may motivate students to understand controversial and current topics and their importance. He mentioned two topics of concern, the Human Genome Project and Biotechnology.

As a result one may assume that most of high school and college students are not exposed to moral, ethical, and human value discussions while learning science and technology. Some of them will later in their lives become science teachers, medical doctors, scientists, and politicians (Gottlieb, 1976), "*Students should be made aware that society became extremely sensitised to the need of ethics in human experimentation after the details of the Nazi atrocities, presumably performed in the name of scientific research, were made public*.".

"How difficult is it to raise ethical, legal and societal issues in the biology classroom and discuss ways to resolve them," asked Lindell and Milczarek (1997).

As such, one might query, "Should science teachers address societal dilemmas (ethics, moral, values, etc.) as part of their educational role, in addition to teaching subjects like genetics, genetic engineering, the human genome, molecular biology, topics in ecology and population issues, and aspects related to human genetic predisposition to diseases?" This question was raised by Dreyfus (1995) who wrote that "*teachers must try to present facts in their wider perspective of some biological principles, such as those of studies of behaviour and ecology. This will enable students to develop the eclectic values of an educated member of society.*" In developing a college course focusing on moral issues, Dennis (1968) wrote, "*I have a strong suspicion that our scientific training is guilty of producing citizens who are a far cry from being able to assume the responsibility of the fraternity of mankind.*"

Following the misuse of psychiatry, anthropology, eugenics, and medicine by scientists and Nazi politicians during World War II, this concern is of great importance. The ready assistance of scientists, Nazis, and ordinary people, led at first to the atrocities of euthanasia by killing German patients, children, and elderly people, and was followed by the killing of Jews, Gypsies, other nationalities, and prisoners of war (Muller-Hill, 1998). Relating to the Nazi atrocities Gottlieb (1976) emphasized the need of ethics on human experimentation. In this study, we investigated (a) high school biology teachers' awareness of societal issues (values, ethics, and moral) while teaching genetics in relation to the subjects taught; (b) teachers' reasons for relating, or not, to those issues in their teaching; (c) the relationships between teachers' responses to the societal issues in biology, years of teaching experience, gender, and religious faith.

HISTORICAL BACKGROUND

This study emerged from the need to relate to the ethical, moral, and human value issues in biology instruction, which evolved from two facts: (1) The findings in molecular biology and technology research and their possible impact on daily life. (2) The eugenics theories developed in many countries and the atrocities, which occurred during War World II.

RESEARCH IN SCIENCE AND BIOETHICS IMPLICATIONS

The molecular biology and genetic engineering sciences received a significant thrust forward when human genome-mapping project (HGMP) was completed and published. The question a society must face is who is authorized to use these very significant findings? Who should be responsible for setting down guidelines to use this information, as well as the moral and ethical issues involved? Scientists

cannot free themselves from the practical and moral responsibilities, since they depend on public and government funds for their research. This may influence probably the possible uses of this significant data, on the development of drugs and medical treatment of diseases and other factors related to the human genome.

SOCIETAL ISSUES AND DAILY JOURNALS

Relating to the critical issues, Wade (2000b) wrote, "Probably almost everyone possesses many genes variants associated with adverse health effects: This information could be used to the individual's detriment, if not kept confidential, and could be psychologically devastating if diagnosis runs ahead of treatment and the physician has no therapy to offer." He continued, "Population geneticists know that all people are extremely similar to one another in genetic terms and believe that the similarities overwhelm the very minor differences that they are studying."

Citing scientists, Wade (2000b) wrote that others fear the differences may not be used so benignly and Dr. A. L. Caplan (ethicist at the University of Pennsylvania) believes geneticists underestimate both the appetite for this genetic information and its potential for misuse. People do not realize how important is that drive to understand ourselves. In most parts of the world we define ourselves by blood and skin, and those are just surrogates for genes. Control of the genome would then fall to some extent under human direction, bringing benefits to health and longevity, but raising a risk of changing human nature in unintended and unwarranted ways. By 2010, the genome will help to identify people at highest risk of particular diseases, thus monitoring efforts can focus on them. He further cites Dr. James Watson who said, "*I think young people are the ones who are afraid to see the future*" and "*old people see the future and would like to reverse it.*"

In relation to cancer diseases, Wade (2000a) mentioned that genetic tests will identify those at highest risk for lung cancer from smoking and diabetes, encouraging susceptible individuals to exercise and control their weight in order to lower the risks.

Concerns about the possibility that insurance companies will deny old or young people the right to life insurance contracts or denied jobs at a certain age, as a result of the public availability of the person's genome map were mentioned by Altman (2000).

The basic question is that who will benefit from such progress in medical treatments, those that have the means; or will other criteria be used? As the accuracy improves and costs drop, many will require the tests to reduce the chances of bearing a child who is at risk of developing conditions that are not actually debilitating, but just "undesirable."

The genome project is promising for people with mental illnesses like schizophrenia and maniac depression to produce new therapies. By 2030, death will still be inevitable, but clinical trials relying on information *from* the genome will be under way to extend human life spans. Relating to this issue, Watson (2000, p. 209) noted that "*those genes miscoded during the DNA replication, lead to human diseases like cancer, diabetes, or Alzheimer. Those pursuing the Human Genome Project invariably will be generating new DNA methodologies pivotal for future advances in biotechnology that is, the use of cells for generating flew commercial products (drugs, diagnostics, food, etc.)*".

If so, there is and will always be the need to debate the relation between morality and scientific research and their impact on human life.

> "Serious consideration was given to whether the novel genetically modified microorganisms (viruses, bacteria, and yeast) created in our laboratories might pose a realistic threat to either human health or the world's ecology," wrote Watson (2000, p. 210).

On August 23, 2000, it was reported on TV that scientists discovered that about 20% of the Monarch butterfly caterpillars were found dead while fed on the pollen of genetically modified microorganisms (GMO) corn plants. Thus, should one be concerned with the ecological threat to the Monarch butterflies population? Is there a potential threat to the human population or animals eating and plants feeding on GMO food?

When the representative of the German Ministry of Science, Ms. Eike Wulfmg said at a meeting in Berlin, that "*research which does not lead to patents had no place in her research portfolio*," Watson (2000, p. 216) noted, "*My feeling of angry despair was compounded when her talk ended without any significant mentioning of the ethical uses of genetic information.*" "*To the contrary American genome effort was committing five percent of its funds to discussion of the ethical, legal, and social consequences of genome research*" (Watson, 2000, p. 218).

The above approach is strongly supported by the following statement of Muller-Hill (1998, p. 206), "*To sum up, it is the duty of human geneticists to predict the possible social consequences of genetic research and to act accordingly. I fear that new eugenics will again become* "*kakogenics*" *with massive misuse of genetic knowledge. I would be most happy if I am proven wrong by history.*"

This may be a very pessimistic view of reality but it could also be a very sober view of science education in universities today, and what it will lead to. Muller-Hill's statement is based on the knowledge that students who study science and technology are not required to enroll in any course which deals with ethics, moral, and human values. The impact and the consequences of developments in science and technology on human society from all aspects (social, health, ecology, etc.) are left to the politicians.

Is this situation the result of opportunism (research funding, promotion, and tenure) or unwillingness by the scientific establishment to take a stand on these issues?

THE RELATIONSHIP BETWEEN SCIENCE, SCIENTISTS, AND SOCIETY

The drug industry, insurance and companies, business competence and the patenting of genes, the determination of the structure of proteins and other vital information are potentially impeding the progress of basic research by hindering the free exchange of knowledge and research reagents (Ehsasn, 1996; Poste, 1995).

In his report, Wade (2000a) investigated the history of the research on the mapping of the human genome. The following are some of his conclusions, which substantiate the theoretical basis and contention of our study:

"*The human genome, the ancient script that has now been deciphered, consists of two sets of 23 giant DNA molecules, or chromosomes with each set, one inherited from each parent, containing more than three billion chemical units. The successful deciphering of this vast genetic archive attests to the extraordinary pace of biology's advance since 1953 when the structure of DNA was first discovered and presages an era of even brisker progress. Understanding the human genome is expected to change the practice of medicine. Biologists expect in time to develop an array of diagnostics and treatments based on it and tailored to individual patients, some of which will exploit the body's own mechanisms of self-repair.*" But he noted, "*the knowledge in the genome could also be used in harmful ways, particularly* in revealing patients' disposition to disease if their privacy is not safeguarded and causing discrimination."

In relation to cancer diseases, Wade (2000a) mentioned that genetic tests will identify those at highest risk: for lung cancer from smoking and diabetes, encouraging susceptible individuals to exercise and control their weight in order to lower the risks.

The following citations from Angier (2000, p. A21) can illuminate the human values which arouse interest, and are related to the mapping of the human genome:

"For some, researchers, the emerging details of the genome sequence are most fascinating for what they say about the fraternity between the human species and all other creatures on earth." And she continued by citing Jon Seger, an evolutionary biologist and geneticist at the University of Utah in Salt Lake City, "You can see the same genes in flies, worms, monkeys, mice and people. Its evolution laid out for all to see. There's nothing peculiar or distinctive about us." Some scientists emphasize the genetic fraternity of humanity. Humans may be genetically similar to mice and monkeys, but it turns out that people are extraordinarily similar to each other: there are far fewer genetic differences, or polymorphism, among different peoples, and people populations, than are observed on members of other species, including ape relatives. This discovery, scientists say, has profound implications for understanding the various human "races."

Wade (2000b; p. Fl) mentioned that as a result of the human genome mapping "The first practical impact will be in health, by developing new drugs with new therapy, while the personal medicine will be tailored to the individual, based on a genome analysis." And citing again Professor A. L. Caplan, Wade (2000b, p. F4) wrote that "Less beneficial may be the power of genetic differences, even entirely inconsequential ones, to divide or be cited as the justification for division and discord. Most geneticists were euphoric that so many of our genes are in common, that the genome map will show us to be a happy band of brothers and sisters." But Dr. Caplan fears that people "will use this information to bolster ethnic prejudices and other exclusivity groupings they believe in."

Referring to the different forms one gene may take in different people. Wade (2000b, p. F4) quoted

Dr. Robert Weinberg of Whitehead Institute in Cambridge, MA, "*There is no doubt that knowledge about different alleles will create the temptation to optimise one's offspring in terms of their genetic endowment. Who will make ethical and moral choices? This has to be a society wide debate*," he said, "*not one involving just geneticists or bio-ethicists*" and Wade concluded that "*along with the benefits comes the temptation of changing human nature.*"

EUGENICS THEORY AND WAR WORLD II

Technological progress and medical experiments can be used to promote society or practices that are cruel and inhuman, as were carried out during the World War II (Muller-Hill, 1998). This problem is aggravated by the fact, as revealed by Muller-Hill (1998) (a) scientists in medicine, evolution, and genetics who participated in the elimination of Jews, Gypsies, and others in Germany, in the years of 1933–1945, were not punished; (b) those scientists and others have continued to use human body organs which were obtained during these criminal experiments, until 1990; (c) these scientists founded their research on their particular racist ideology in order to prove it; (d) they continued to be prominent scientists in Germany, holding positions as heads of important institutes and projects long after the war. The reaction to these activities was silence in, the scientific communities all over the world. No effort or trial attempted to isolate these scientists or to react to their activities until very recently (Watson, 2000). German scientists who performed experiments on human beings during War World II, in order to legitimize racial and Nazi "*scientific theories*" were allowed to present their findings at international conferences years after the war. Scientists from the free world attended these conferences, and no one objected to or rejected their presentations. In addition, there are accusations that some of the "findings and information" obtained by them on Jews and Chinese in Germany and Japan were used by scientists in the free world as well (Levi, 2000; Muller-Hill, 1998).

A wall of silence in Germany was erected around the publication of the Muller-Hill book (1998). In his review of the book, Yee (1998), wrote that Muller-Hill had described the use of the victims by Dr. Mengele, who performed "scientific experiments" in Auschwitz, and scientists who benefited from the ready supply of skulls, brains, eyes, and other body parts provided by the killing of the victims.

GERMAN SCIENTISTS AND THE HOLOCAUST

How can one explain the fact that German psychiatrists and anthropologists participated in the Holocaust? What led these doctors and scientists to become involved in this distressing perdition? Why was the extermination of Jews and mental patients kept secret? What can we learn about anthropology and psychiatry from the experiment of National Socialism? Was there any resistance, first within the scientific community and then by the ordinary educated people, except for very, very few? These scientists had been educated in sciences by high school teachers and university professors. Is it possible that they were "educated" to deal primarily with scientific facts, concepts, and principles, but not relating them to moral, ethical, and human values? Were their teachers able, ready, and prepared to tackle these issues in their teaching? Can we relate the same questions to the teachers of our time? In the chapter "The Specter of Kakogenics" of his book, Muller-Hill (1998 p. 201 and p. 206) highlights the danger of a revival of eugenics and argues that, while science produces truth rather than values, scientists are basically responsible for the use of their research, particularly if it provides information to those who use it for criminal activities, including murder. It would seem incumbent on them to be aware of how their research results are used.

A "Reader from the United States," (2000), reviewing the Muller-Hill book (1998), mentioned that this study examines two issues that demand the attention of anyone interested in science, history, and society. The first is the story of how German scientists who were pioneers in the study of genetics of human populations lent their scientific prestige to the mind-numbing brutality of the Nazis. Their scholarly works on "Race-hygiene," with its barely disguised anti-Semitism, led to the sterilization of thousands of "undesirables" in the 1930s under the guise of scientific acceptability, and then escalated into the industrial scale murder known as the Holocaust. A second major thread is how scientific perpetrators such as Professor Verscher and his student, the more notorious Mengele, survived the war and in Vescher's case he continued to be honored by European scientific societies into the 1960s. Not just German, but British,

French, Italian, and American scientists chose to turn a blind eye and present awards to the collaborator in Mengele's Auschwitz "twin-studies."

The Muller-Hill (1998) discoveries and publications were met with stony silence, and the closing of archives and papers to the public. His book is probably the most thorough and well-documented account of this issue for many years to come and as such served as a stimulator to perform this study.

THE EUGENICS THEORY

Were the Germans the pioneers of the eugenics theory (a concept of two words in Greek, good and generation)? In his review, Kirnmerling (2004), on the basis of a set of books, noted that before War World II, there was a sad chapter in the history of United States (Black, 2003; Carlson, 2001, Khul, 2002; Ordover, 2003).

The American Eugenics Society (AES) advocated between the two world wars against immigration of non-Nordic people in order to keep what they called "humanity purity" or "improvement." AES ideas were based on the theory of anti-miscegenation (marriage between races) developed by the British anthropologist, Francis Galtung in 1883, who scientifically explained the Mendel genetic laws through mathematical equations, aimed to justify their care for the Nordic race and on behalf of the humanity. The AES supported the race improvement by sterilization of those people who are not useful for society. Some of their advice was physical extermination as an act of mercy and grace without their knowledge, while they sleep. The AES was against mix-marriages and people who do not fit. It advocated embryo abortion with couples who had not been sterilized in time and belonged to the unfit groups of people. These people included immigrants from across Europe, Blacks, Jews, Mexicans, Native Americans, mentally ill, who carries genetic diseases and disabled, criminals, alcoholics, intoxicated, epileptics, prostitutes, homosexuals, or just people defined as immoral. The list finally included all those who did not resemble the blond and blue-eyed Nordic ideal glorified by the eugenics movement. No wonder that through international academic exchanges, American eugenicists diffused world-wide the movement. We know that the Nazi and their scientists performed these recommendations on Germans people before the war and on the Jews, Gypsies, prisoners of war, and political persons during War World II. There were scientists and other intellectuals who fought against the idea of improving the "American race." They argued to the contrary, that findings of the genetics theory had to lead to opposite societal and political conclusions since by inter-marriage, the genetic illnesses and deformations are minimized. However, their impact was unheard.

In those days, even the *Journal of the American Medical Association* (*JAMA*) was almost the journal of the movement for improving the race (eugenics). Following World War II and gathering the information about the Nazi atrocities, the AES almost disappeared, but not their ideas (Black, 2003). In 1956, Prof. William Shockeley from Stanford University, who received the Nobel prize in Physics, known for the invention of the transistor and the development of the telecommunication system and the computer, was well known for his societal theory too. He argued that the welfare state policy lowers the quality of the human species, since it is clear that those who need welfare suffer from a low intelligence quotient (IQ). As a result, the State support of these people acts against the natural selection versus those who have higher ability to survive. In his opinion the human development depends on the 2% of those who have a higher IQ level based on the classic Bell Curve Herrenstein and Murray (1994). In the last years, Cold Spring Harbor Laboratory Press published the book, "*The Unfit: A History of a Bad Idea*" by Carlson (2001). Under the leadership of A. J. Watson, the book by Muller-Hill (1998), "*Murderous Science: Elimination by Scientific Selection of Jews, Gypsies and Others in Germany, 1935–1945*," was translated to English and published by the Cold Spring Harbor Laboratory Press in United States. In Germany, until today, no publisher agreed to publish this book. From the examples mentioned above, one can see the responsibilities scientists bear.

LITERATURE SURVEY

High School Biology and Societal Issues

In her study, Rosenthal (1984), found that between 1963 and 1983 attention to societal issues decreased in high school biology textbooks. Those books had minimized the controversial aspects and avoided questions of ethics and values, lacked a global perspective, and neglected the interdisciplinary nature of problems. Her conclusion was that

while some bioethic aspects were mentioned, almost none of the societal problems such as environment, population, and human behavior were referred to in the books of the 1980s, contrary to the books of 1973. The general picture showed a declining emphasis of societal issues on the school textbooks.

Conner (2000a) investigated the subjects of inquiry, discourse, and meta-cognition on promoting students' learning in a bioethical context during the final year of high school biology. According to Macer (1994), bioethical contexts explore ethical issues in relation to decision-making on the use of organisms and their role in developing new medicines. Conner (2000a) mentioned that "*the aim of including bioethical issues is to provide opportunities for students to be prepared to respond to issues in adult life by giving them experience in discussing personal, social and ethical dilemmas related to science and technology.*" This approach is further emphasized by Solomon (1993), who wrote that in a society where the impacts of technology need to be explored and elaborated, future citizens should be informed in order to make independent and objective decisions.

Layton (1993) advocated the need to incorporate those societal issues that are associated with science and technology subjects into science curricula.

However, Conner (2000b) suggested that "*snippets here and there have no impact on either students' learning of the associated scientific concepts or their regard for social and ethical issues*." Regarding this issue, Rubba *et al.* (1991) found that "*inserting STS vignettes had no effect on students' awareness of issues, the perceived importance students assign to current STS issues or their achievement levels in a unit on genetics as measured by teacher-made tests*."

Relating to the instructional mode which can be used in order to relate to societal issues, Gilbert and Hoepper (1996) mentioned that social interaction is essential for creating situations which can challenge, refine, and affirm our values. Teachers must create open and supportive classroom discussions in which students bring a wide range of viewpoints and evaluate issues from their personal point of view (Dawson, 1998). Classrooms should be a place where students can develop and acquire skills on critical thinking (Siegel, 1988). Students should get learning opportunities which require the use of higher thinking skills, such as analysis, synthesis, critical reflection, and evaluation of their ideas about social and ethical issues. These should be provided in the context of learning topics, which are relevant to students (Lipman, 1991, p. 50).

Meanwhile, referring to science and technology teachers, Conner (2000c) raised the problem that since they are often only specialists in their subject matter, they may encounter pedagogical difficulties which require discourse on STS issues. The need for guidance in these matters is probably pivotal in order for them to be able to act as facilitators on these issues.

The need for a "*cross-curriculum approach among natural and social sciences and classical culture*" in order to develop positive ethical and aesthetic attitudes about the role of human beings in nature was raised by Lillo and Lillo (2002, p. 137). They developed a set of learning activities on the subject of how Greeks and Romans understood nature. This issue, in their opinion, is very important in order to disprove education in a time of political and economic globalization. They suggest that this approach can be easily adapted in other contexts.

There are several studies in which an attempt was made as to how to encourage students to deal with the societal issues while learning the relevant subject matter. In her study, Conner (2000c) reported that students were encouraged to use an inquiry approach in order to promote students' awareness and communication of the biological, societal, and ethical issues associated with the subjects on cancer diseases. Teachers' role was to engage the students in open and critical discourses in order to acquire learning skills. The students reported that this mode of learning broadened their ideas about bioethical issues linked to cancer.

At the college level, Sadler and Zeidler (2005) explored how students negotiate and resolve genetic engineering dilemmas. They reported that students demonstrated "*evidence of rationalistic, emotive and intuitive forms of informal reasoning*" and most of them "*appreciated some of the moral implications of their decisions*." Sadler and Zeidler (2005) concluded that science classrooms are environments where in addition to reason, intuition, and emotion are valued.

Therefore, the issue is not only one that relates to the social, moral, and ethical values involved in teaching genetics, molecular biology, genetic engineering, and their use and impact on society. There is a more incisive need to relate to the use of the technology and science by scientists and politicians, their attitudes and behavior displayed before and following War World II and to debate on the issues involved.

Method

In this study, the following questions were investigated:

1. Are high school biology teachers aware of the social dilemmas while teaching subjects in genetics?
2. What are the subjects in genetics that, in the teacher's opinion, should be taught in high school?
3. Do these subjects include societal issues (values, moral, and ethics)?
4. What are the reasons given by the teachers in favor or against including societal issues in their classes of genetics, molecular genetics; genetics engineering, and evolution?
5. Do teachers differ in their opinions as to their awareness of these issues due to their years of teaching experience, gender, or religious faith?

The sample consisted of 30 biology teachers (female, $N = 25$, 83%; male, $N = 5$, 17%) in urban and rural high schools. Seven teachers (23%) had teaching experience of 5 years; 9 teachers (30%) had teaching experience of 6–10 years, and 14 teachers (47%) had teaching experience of 11 years and more. Regarding religious faith, six teachers (20%) were identified as being orthodox; 5 teachers (17%) as being traditional, and 19 teachers (63%) as being secular. The small sample is due to the fact that very few biology teachers choose to teach the 5-point level of either genetics or evolution (the highest level required for the matriculation exams of students at the 11th and 12th grades). Teachers of these subjects were approached either by mail or personally by the researchers and asked to participate in the study. Therefore, the sample can be considered of reasonable size, representing the teachers' population teaching these subjects.

THE RESEARCH INSTRUMENTS

Personal information and professional opinions of the teachers were gathered from questionnaires and individual interviews carried out by the researcher.

Teachers' Questionnaire (TQ)

The questionnaire was divided into two parts. In the first part, teachers were asked to provide personal information; gender, years of teaching experience, and religious faith (orthodox, traditional, or secular). The second part consisted of seven open questions on the topics taught (molecular genetics, genetics engineering, human heredity, evolution) and teachers' opinions on the related topics as follows:

1. List the main topics in genetics, molecular genetics, genetic engineering, and human heredity and how this content is related to the subject of evolution that you teach in your classes.
2. What subjects in the above-mentioned topics do you emphasize the most?
3. If you were asked to change parts of the curriculum regarding these topics, which subjects would you recommend to extend?
4. If you were asked to include the topic of Cystic Fibrosis (CF) in the curriculum, into which subjects would you integrate in it?
   a. Are there other issues concerning CF that you would relate to in your teaching?
5. If you were asked to integrate the topic of the Fragile X Chromosome Syndrome (FXCS), in the curriculum, what related subjects would you like to include?
   a. Which issues on FXCS would you relate to in your teaching?
6. If it was in your power to change or add content in your textbook, what topics on human heredity and genetic engineering would you suggest?
7. What subjects would you suggest to integrate into the teaching on the topic of embryo's cloning?

TQ Validity

The study goals, research questions, and the TQ were given to two science educators, two biology scientists, and two biology teachers. They were asked to check the TQ content validity regarding (a) the suitability to curriculum and research goals; (b) the content of the questions, their readability and fitness to serve the research sample; (c) suggested changes or corrections in order to improve the content and the phrasing of the questions if needed; and (d) new open questions which may promote the study goals.

These ideas and suggestions contributed to the phrasing structure of the seven questions. Questions 4 and 5 were each split into two parts. Then the

questionnaire was sent to the teachers by mail or handed to them by the researcher.

Individual Interviews

Because of the small size of the sample, all the teachers ($N = 30$) were interviewed *sad* tape recorded by the researcher, with their permissions.

There are three types of interviews: (a) Open, ethnographic; (b) Standard-constructed (with planned time-table); (c) Guided-Focused (not time-table planned) (Sabar-Ben Jeshua, 1997).

The Guided-Focused Interview was found to be adequate for this study. According to Sabar-Ben Jeshua (1997), this type of interview is based on a manual, with detailed questions related to the study goals; however, their phrasing and order are used in a flexible manner. The respondent had the freedom to reply and react and the interviewer could react to the new points raised by the interviewed.

The advantages of this type of interview are (a) individual reactions; (b) effective use of time; (c) consideration of important points; (d) focus, but the person interviewed is free to react and present ideas. Thus the respondents' answers can be compared, clustered, and analyzed.

One of the problems in this study was to verify and crystallize specific subjects suggested by the teachers, particularly if they also included societal issues. Some questions were used with each respondent, but with a few small deviations from the planned written interview, in order to obtain more information. As a result the respondents brought up subjects and ideas not intended or mentioned in the planned interview, but adding increased substance to the study.

Analysis of the Data

1. Teachers' answers in the questionnaire were clustered into categories and validated by two biology scientists and two biology teachers who taught genetics in high schools. The validation process consisted of several stages.
   a Teachers' answers to each question were gathered from all the 30 questionnaires.
   b. The answers were divided into groups according to their common meaning if repeated.
   c. Each group of answers got a title category.
   d. At this stage, every item in each category was checked to verify the category into which it had been placed.
   e. Each category and classified items were carefully scrutinized.
2. The four experts formed two mixed groups. One group dealt with the categories as were set by the researcher and the teachers' answers. They were asked to relate to the category formed by the teachers' answers, and to suggest changes, transfers, additions, or accept the categories as they were. The other group dealt only with noncategorized teachers' answers, and were asked to classify them into categories according to their judgment.

This procedure was based on Erickson's statement (1986), "*One enters the field with no preconceptions, and learns the methods by doing it. After tremendous emotional stress one finally induces grounded analytic categories*."

The procedure yielded four main categories: (a) Genetics Population; (b) Molecular Genetics; (c) Genetic Engineering; (D) Societal Issues: values, moral, and ethical implications. Additional categories were Practical Issues, General Scientific Subjects, and Pedagogical Issues. Teachers' answers were analyzed according to categories for each research question and to years of teaching experience, gender, and religious faith (secular, traditional, and orthodox). Each category and the number of items on the specific subjects is presented with the analysis results for each research question.

Data Reliability

The triangulation procedure was used in order to ensure data reliability, based on following research sources: Questionnaire answers, interviews, textbooks, and occasional conversations.

Additional strategies to ensure higher reliability are as follows:

a. Teachers were asked during the interview to answer verbally several questions from the questionnaire. Their answers were compared with those provided in the written form.
b. During the interview teachers were asked questions liable of "planting" or "seeding" the required answers, but teachers' responses were not affected and they proved to be authentic.

In order to illustrate this procedure, here is one example:

Planted question: "Do you think that it is important that you should include in your teaching more humanistic and societal issues like values, moral, and ethical subjects, to be related to the science curriculum in your lessons?"

Teacher's answer: "Perhaps it is important, but I prefer to teach subjects which will help the students to succeed in the matriculation exams."

Other teachers replied that in their textbooks they did not find societal issues and values related to the topic, and therefore did not have the didactical tools to integrate them in their teaching.

RESULTS

Teachers' responses to question 1 were clustered in four categories as presented in Table I.

The results show that most of the 125 resopnses belong to scientific categories. The number in parentheses, which follows a category, indicates how many times it was mentioned: basic genetics (76 items, 60%); molecular genetics (24 items, 19%); and genetic engineering (18 items, 14%). Only 7 items (6%) related to the societal implications category.

While one compares the number of topics between the scientific subjects and the societal issues then a big gap of 118 items vs. 7 items only becomes obvious. Topics primarily emphasized were genetic diseases, Mendel principles, sex determination, and blood types in Basic Genetics and Population categories. In the second category, genetic engineering and application of medicine and agriculture were emphasized. Only three teachers mentioned the seven items in the societal implication category. The results in Fig. 1 illustrate even better the existing gap.

Teachers' responses to question 2 were gathered in the same four categories and are presented in Table II.

The results show about the same distribution between the scientific categories and the societal implications as in Table I, regarding the question related to what teachers will mostly emphasize in their teaching. Although the responses are different in content, the same ratio appears between the scientific items and the societal ones. On this question, 25 teachers answered, but only 4 of them mentioned societal issues. Teachers' responses to question 3 were clustered in three categories presented in Table III.

Only 13 teachers answered this question and three categories were identified, as being based on 18 responses. Ten topics were suggested for the scientific and practical categories and six for the societal one. While teachers were willing to add ethical subjects, they preferred specialists to deal with genetic counseling and subjects like limits acceptable or prohibited regarding the genetic engineering issue. They indicated that they themselves were ready to deal with ethical problems. Again, while on scientific and practical subjects they were ready to add topics to their instruction, there was a tendency to refer the societal issues to others.

Teachers' responses to question 4 were clustered in two categories presented in Table IV.

It can be seen that if required to add to their curriculum the topic of Cystic Fibrosis disease (CFd), what subjects they will integrate, they referred to 43 items on the scientific field and only 5 related to the societal area. This topic is not in their curriculum and is not found in the textbook they used. Though mentioning scientific topics, teachers did not necessarily manifest knowledge about the disease. Moreover, the majority of the teachers did not find it necessary, or simply did not consider it their role to relate to the societal aspects of the problem. It remains to be determined if teachers lack sensitivity to societal issues or do not regard it their role as science teachers to include values and ethical aspects. One might recognize the need of including these aspects in teacher education.

When they were asked on the second part of the question 4a as to what subjects of the CFd topic they would relate as a teacher, they mentioned 42 items which were clustered in three categories: scientific (20 items, 48%); pedagogical (6 items, 14%); societal issues (16 items, 38%, provided by 9 teachers out of 30). The results are presented in Table V.

On question 5, when asked as what subjects on the topic of Fragile X Chromosome Syndrome (FXCS) they would like to integrate in their curriculum, teachers suggested 44 items: 41 of them on the scientific and only 3 related to societal aspects. The results are presented in Table VI.

To question 5a in the second part what subjects on the topic of FXCS they would relate as a teacher, they mentioned 23 scientific items and only 5 societal issues (Table VII).

Questions 4 and 5 yielded the same ratio of responses between the scientific and societal subjects related to CF and FXCS.

Table I. Distribution of Teachers' Answers to Question 1 by Categories

Genetics topics	Molecular genetics	Genetic engineering	Societal issues
Genetic diseases (12)	Mutations (6)	Genetic engineering (6)	Ethics (3)
Mendelian principles (6)	Molecular genetics	Medical and agricultural (5)	Importance of early identification of applications genetic diseases
Sex determination (9)	Genes and their effect on characteristics (3)	Dolly—the cloned sheep	Genetic counseling for families
Blood types (6)	The Operon model (2)	Biotechnology (2)	Use of hereditary principles for the well-being of man
Learning genetics based on textbook (3)	Gene regulation	Diagnosis and mapping of genes	Heredity and environment
Sex-linked characteristics (3)	Chromosome structure	Species selection and modification	
Population genetics (2)	Factors influencing mutations–mutagens	Plasmids	
Codominance (2)	Chromosome mapping	Research methods for laboratories in genetic engineering	
Family tree lineage (2)	Genetic microbiology		
Crossing-over (2)	Induction and repression in DNA replication		
Gene linkage (2)			
Mitosis/meiosis (2)			
Basic concepts (2)			
Alleles and multiple alleles (2)			
Heredity and acquired characteristics (2)			
What is heredity?			
Resemblance between parents and children			
Probability			
Fertilization			
The influence of diseases on the distribution of characteristics in a population			
Genotypes			
What enables the cell to transmit hereditary traits?			
The heredity of autosomes			
The heredity of man			
The Hardy–Weinberg Law			
Mating of kin			
No. of items[a]			
76 (60%)	24 (19%)	18 (14%)	7 (6%)

[a]Total no. of items: 125.

In question 6 teachers were asked that if they would be authorized to change or add to their genetics textbooks which included topics on human heredity and genetic engineering, what would they suggest? Only 21 items were provided by the teachers and those responses were clustered in two categories: scientific and societal areas, presented in Table VIIII.

Only 12 teachers suggested 16 (76%) changes and additions to the scientific content related to genetic engineering, to update the content. As to the societal area, two teachers referred to the consequences on the use of genetics engineering, the need of articles on moral issues, euthanasia, genetic cloning, and the application of genetic engineering to human problems (5 items, 24%).

In question 7, teachers were asked to suggest topics on the subject of embryo cloning that they would like to integrate into their teaching. The responses were clustered into two categories presented in Table IX.

The results show that the teachers ($N = 17$) suggested 27 items, equally divided into two categories:

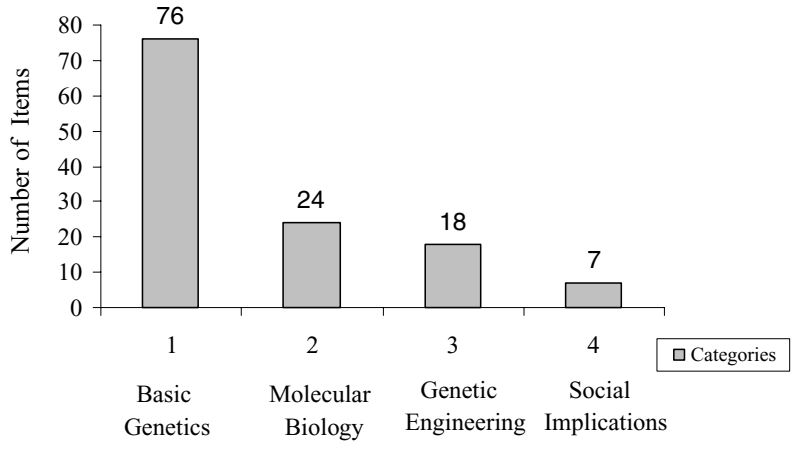

Fig. 1. Histogram summarising data presented in Table I, teachers' answers to question 1 by categories.

In the scientific area, 14 items (52%) and on the societal issues 13 items (42%). The results give the impression that were stimulated by these areas most of the teachers. The teachers were concerned with the scientific content and the ethical aspects of human cloning, including the Dolly experience and charlatans and dictators who could use biotechnology for their purposes. One might wonder whether this reminded them of the "Nazi theories" on superior and inferior human races? The issue of effectiveness vs. ethics was raised as well, and, as a result, their reaction was strongly on the affective domain.

Finally, teachers' responses on question I were analyzed also by years of teaching experience, gender, and faith. The answers distribution to question 1 are presented by categories and years of teaching experience in Fig. 2 and in Table X.

There is a similar pattern of responses by the three groups of teachers relating to teaching experience. The greatest numbers of items are in the first column, Basic genetics, followed by the other two groups, while the smallest number of items can be found in the societal issues column. The only significant differences are between the most experienced teachers and the other two groups in all the four categories. Teachers with more years of teaching experience tended to provide more items in the four categories. One might expect that novice teachers would provide more items on Basic Genetics, Molecular Biology, and Genetic Engineering, because of the fact that they had recently concluded their university studies, but this was not the case. There is no indication that university studies had any particular impact on these issues; obviously, they preferred to stick to their textbooks. On the other hand, the teachers with 11 and more years of teaching experience felt more secure in surpassing their textbooks, and expressed more willingness to deal with new scientific subjects and with more issues that could lead to discussion on the affective domain. These results lead to assume that experienced teachers felt more secure in introducing issues and subjects in their teaching beyond those in their textbooks. Those teachers could be considered as being in their third stage of professional development according to Fuller and Parson (1969).

They had probably overcome the survival period and the insecurity of not knowing enough about science and pedagogy. In this third stage they feel secure enough to address students' needs in terms of providing new and up to date learning material and relate to students' interests. Thus they are able to include affective values and ethical aspects, and use science in their daily life.

The results indicated that the four categories presented in Table I did not show any significant differences by gender and faith. The answers in the four categories showed no gender difference nor difference according to orthodox, traditional, and secular teachers. Since the teachers' answers related to gender and religious faith were fou nd not significantly different, they are not reported.

DISCUSSION

The results indicate that among the teachers who participated in this study there is a medium to

Table II. Distribution of Teachers' Answers to Question 2 by Categories

Basic genetics and populations	Molecular genetics	Genetic engineering	Societal issues
Diseases of man (5)	The relationship between mutations and recombination (2)	The definition of genetic engineering (3) and its importance to the development of immunizations, drugs, the identification of hereditary diseases (2)	Through these subjects one can develop other aspects of the problem
Sex-linked characteristics (2)	Molecular biology (3)	Recent universal interest in the subject makes the student more aware of it (2)	Consequences of information on one's life. Improvement of species by scientific hybridization
Bringing the topics closer to students' life (2)	The relationship between phenomena and biochemical explanations	Advancement in the interbreeding of species (2)	Genetic engineering—pro and con
Topics of great interest to the students (2)	The relationship between biological processes and the regulation of genes	The use of new methods in genetic counseling (2)	The significance and meaning of genetic engineering
The foundation for the knowledge and understanding of heredity		The applications of genetic engineering	Interests the students and influences their questions
Population genetics		Inhibitory enzymes and their use	The ethical questions arising from the use of genetic engineering
The Operon model		Recent topics and research performed on them today	The Genome Project of human DNA and its ethical consequences
Chromosomes instruction guided by the curriculum			
Basic subjects in genetics			
Hereditary diseases in families			
Blood types			
Basic concepts			
Principles of heredity			
Determination of sex			
The relationship between the phenotype and the genotype			
Mendelian genetics			
Traits as affected by heredity/environment			
No. of items[a]			
25 (48%)	7 (13%)	14 (26%)	7 (13%)

[a]Total no. of items: 53.

low level of awareness of societal issues, and the main emphasis is on the "pure" by scientific subjects taught for the matriculation exams. Most of the teachers do not include societal issues in their classes, as a planned part of their curriculum, but if students raise these issues, the teachers claimed to address them. No differences in the teachers' opinions to societal aspects were found related to gender and religious faith. Teachers with more years of teaching experience tend to teach genetics with more of a STS approach than novice teachers. The novice teachers prefer to "stick" to basic and mandatory subjects. The teachers explained not including debates on societal issues as an integral part of teaching genetics as follows: their preoccupation with the matriculation examinations; their having to focus on subjects to be tested in these exams; and having no time to prepare the students to them. All this drives the teachers to "stick to" the curriculum and teach it without any enrichment. Therefore, many teachers refrain teaching related to societal issues, which might have a moral or value orientation, but they are not part of the mandatory curriculum. One might assume that these attitudes are a result of the teachers' unwillingness to take a stand on issues that are not clearly part of the curriculum and could contradict school policy and parents' values. Another explanation could be if tools are given to the teachers in

Table III. Distribution of Teachers' Answers to Question 3 by Categories

Additional scientific issues	Additional practical issues	Additional societal issues
The elucidation of genetic principles through the study of diseases of man and other organisms (3)	Performance of laboratories on the subject of genetic engineering	Emphasis on ethical problems (2)
The development of biotechnology	Visit to a laboratory that concentrates on the growth of cells taken from amniotic fluid	Lectures on genetic counseling by specialists
New information that is being derived from current research	Tour to an institute that is engaged in the genetics of plants and animals	Lectures on the subjects of the limits that are acceptable or prohibited in genetic engineering
Curing done by changes in the genome—an instance being the curing of cancer	Additional laboratories	The moral implications of genetic engineering
The lack of sufficient experience—(drill)		
No. of items[a]		
8 (45%)	4 (22%)	6 (33%)

[a]Total no. of items: 18.

textbooks, pro-service and in-service teacher education courses in which they should acquire skills and confidence needed to lead debates during science classes, so that students could make decisions based on evidence and not on prejudice and misconceptions. Another explanation for not relating to societal issues can be, according to Hugbes (2000), "*Teachers fear that extensive coverage of socio-science devaluates the curriculum, alienates traditional science students and jeopardises their own status as gatekeepers of scientific knowledge.*" But Zobar and Nenet (2002) have shown that by integrating explicit teaching of argumentation into the instruction of dilemmas in human genetics enhances the performance in biological knowledge and students were able to transfer reasoning skills to the context of dilemmas taken

Table IV. Distribution of Teachers' Answers to Question 4 by Categories

Scientific issues	Societal issues
Mendelian laws as applied to (autosomes, recessives) (6)	Ethical subjects (3)
Genetic counseling (6)	The right to abort an embryo that carries a genetic disease
Diagnostic methods (5)	
Genetic diseases (4)	
Treatment of genetic diseases (2)	
Mating of kin (2)	
Symptoms (2)	
Sex-linked characteristics	The danger involved in them
Genotype, phenotype	
Population genetics	
The causes of disease	
The probability of developing the disease	
The identification of carriers of a specific disease	
The absorption of materials into the cell and their affect on other processes	
Hardy–Weinberg law	
The treatments of like diseases	
Acceptable techniques	
Genetic diseases in contrast to diseases that are not genetic	
Rate of penetration of these diseases	
Manner in which these diseases have been expressed	
Genetic mapping	
Carrier	
Family "trees"—ancestry	
No. of items	
43 (90%)	5 (10%)

Table V. Distribution of Teachers' Answers to Question 4a by Categories

Scientific issues	Pedagogical issues	Societal issues
Genetic counseling (5)	Do these issues tend to create fear or deterrence?	Ethical questions—i.e., cessation of pregnancy due to early diagnosis (2)
Diagnostic methods used in genetics	Do these subjects stimulate interest in the classroom?	
Factors that lead to symptoms of the illness (i.e., lack of enzyme, etc.) (2)	Are there children in the classroom whose families carry genetic illness?	Ethical attitude of the doctor, abortions (2)
		Where should one be diagnosed
Type of treatment used to heal the illness	To what degree should one delve without burdening the student?	The need/right to abort a defective embryo
How does one prevent the spread of the disease?	Misconceptions	Dilemma—examination of amniotic fluid—advantages and deficiencies
Which chromosome is involved?	Strategies for teaching this issue by involving the mitosis/meiosis concepts	What is a genetic defect—determination of this concept
Parental blood tests in order to detect the possibility of illness in their progeny		Our privilege to interfere—where it can lead
Why is this genetic disease so prevalent?		Ethical questions—selection of defective embryos
Genetic mapping		
When does the disease appear?		
The frequency of disease appearance		
No. of items[a]		
20 (48%)	6 (14%)	16 (38%)

[a]Total no. of items: 42.

Table VI. Distribution of Teachers' Answers to Question 5 by Categories

Scientific issues	Societal issues
Sex linked (9)	Ethics—If one is a genetic counselor, what advice would one give to a family that carries this defect?
Codomination (7)	
Hereditary diseases (7)	
Genetic counseling (3)	The moral consequences—How should one weigh the results?
Family "trees" (2)	
Genetic testing (2)	
Testing amniotic fluid	Abortions—pro and con
Autosomal genes	
Degree of retardation	
Methods of diagnosis	
Homozygous/heterozygous	
Mendelian heredity	
Probability	
Genetic expression	
Identification of diseases before and during pregnancy	
Mating of kin	
Method of testing	
Carriers of disease	
Deviation from normal karyotype	
Probability of transmission of disease to following generations	
Heredity of sex	
No. of items[a]	
41 (93%)	3 (7%)

[a]Total no. of items: 44.

Table VII. Distribution of Teachers' Answers to Question 5a by Categories

Scientific issues	Societal issues
Sex linked (3)	Morality of abortion of embryos (2)
Codomination (3)	Awareness of man's moral and religious problems
Why are some of the individuals ill whereas others are not (2)	The privilege/restriction of carriers to become pregnant. To what degree is the government "responsible"?
Genetic testing	Determination of parentage
Diagnosis preceding birth	Manner in which the disease is inherited
Blood tests for other diseases	
What are the technical possibilities of identifying various conditions in the blood?	
Is there a possibility for early detection of a phenotype that has the probability of carrying the genetic traits?	
Homozygous/heterozygous	
Gene expression	
Can one prevent the spread of the disease?	
Genetic consultation	
What is the reason for the fact that heterozygous females are ill?	
Hereditary diseases	
Gene mapping	
Carriers of diseases	
No. of items[a]	
23 (82%)	5 (18%)

[a]Total no. of items: 28.

from everyday life. Therefore strategies of leading class discussions on societal issues bounded to subjects' matter should be developed and investigated in the future.

School policy, teamwork, and the teacher's perception of their role can also be reasons for not including societal issues in teaching genetics. Therefore, Gershon (1993) asked "*what is the responsibility of the scientific community? Is and should science be neutral? Can knowledge be ethically dangerous? What is potentially more dangerous: knowledge or ignorance?*"

The answer to this question was actually answered during WWII, when on the one hand the fraudulent use of knowledge led to genocide, and on the other hand ignorance was responsible for it as well. Citing Watson (2000, p. 3), who wrote "*knowledge would liberate mankind from superstition,*" one

Table VIII. Distribution of Teachers' Answers to Question 6 by Categories

Scientific issues	Societal issues
Genetic engineering (4)	The consequences of genetic engineering
Skill proficiency (2)	Articles that deal with moral issues: mercy killing, genetic cloning, the use of genetic engineering for the betterment of man, and the problems that arise from these issues
Biotechnology	
Quantitative biology	
I would lower some of the questions and wordage to the level of 3 units	
Actualization	
Diseases that are the result of the mating of kin	
Up-to-date information in genetics in recent years	
Selected reading and enrichment	
Depiction through the use of research and discovery	
Illustrations and sketches	
Pictures and photographs of phenomena and defects	
No. of items[a]	
16 (76%)	5 (24%)

[a]Total no. of items: 21.

Table IX. Distribution of Teachers' Answers to Question 7 by Categories

Scientific issues	Societal issues
The biotechnology of embryonic cloning (8)	The ethical and moral consequences (8)
Natural reproduction in contrast to reproduction that takes place in cloning	Dolly—The cloned sheep—and the ethical problems involved
Cloning of animals	The fear engendered by the possibility of dictatorships and charlatans (Nazis and the "Aryan race")
Replication in contrast to cloning	Comparison
Maternal heredity	
Molecular heredity	
No. of items[a]	
14 (52%)	13 (48%)

[a]Total no. of items: 27.

may add that liberation from ignorance, prejudices, and poverty not necessarily predict that circumstances cannot repeat themselves in the future. One may ask if it is the role of the universities to offer college courses on societal issues and bioethics (morals, ethics, and values) not only in the philosophy departments but in that of sciences and technology too. The pre- and in-service courses for science teachers who teach genetics, evolution, and related topics should include opportunities to discus these issues in class as well (Muller-Hill, 1998, translator preface, Fraser, p. xii).

The roles of teachers at all levels should not be based on solely "dry" knowledge, but to address these societal issues in open discussions, giving every one the opportunity to take a stand on science and technology developments. Only then we will be able to say that educating through the teaching science and technology can be relevant to students' needs as future citizens of our society. Knowledge cannot be neutral, it can only be human.

RECOMMENDATIONS

The findings of this study show the need for the implementation of discussions on societal issues related to science, technology, and environment. In order to facilitate it, it is necessary to include these components in teachers' pre- and in-service education programs in science and technology university level. High school curricula should also

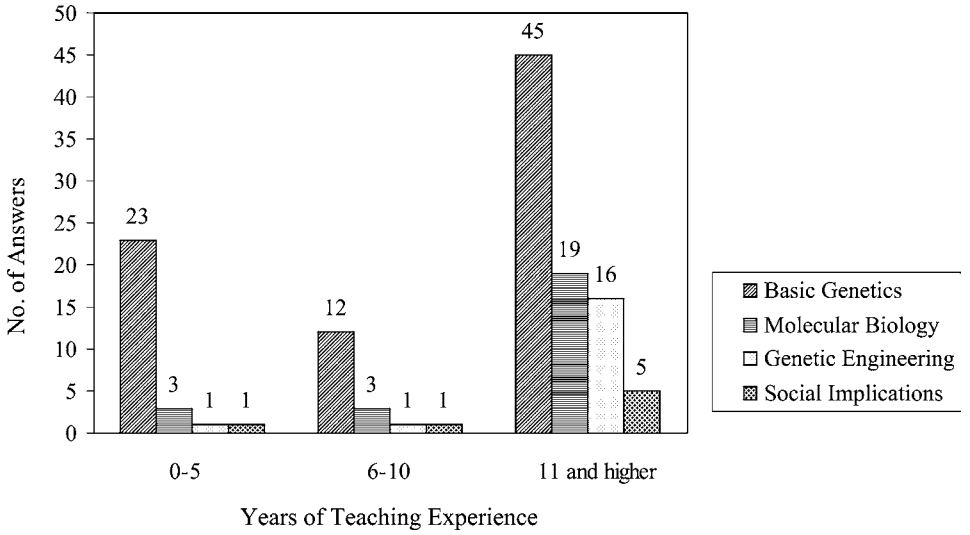

Fig. 2. Distribution of teachers' answers by years of teaching experience.

Table X. Distribution of Teachers' Answers to Question 1 by Categories and Teaching Experience

Genetics topics	Molecular genetics	Genetic engineering	Societal issues
0–5 years of experience			
1. Genetic diseases (3)	Molecular genetics (2)	Genetic engineering	Ethics
2. Mendelian genetics (3)			
3. Blood types (3)			
4. Sex linked (2)			
5. Determination of sex (2)			
6. Characteristics determined by genes and or environment (2)			
7. Dominance			
8. Hardy–Weinberg Law			
9. Basic concepts			
10. Mitosis/meiosis			
11. Codominance			
12. Autosomonal heredity			
13. The heredity of man			
14. Content of studies in accordance with Atidya text (1990)			
No. of items in column (distribution in percentage)			
23 (82.1%)	3 (10.7%)	1 (3.6%)	1 (3.6%)
6–10 years of experience			
1. Mendelian genetics	Molecular genetics	Plasmids	Use of genetics for the good of man
2. Content of cell that makes heredity possible	The Operon model		
3. What is transferred in heredity?	Mutations		
4. What is heredity?			
5. Hereditary diseases			
6. Mitosis/meiosis			
7. Probability			
8. Fertilization			
9. Determination of sex			
10. Family "trees"			
11. Sex linked			
12. Heredity by alleles and multiple alleles			
No. of items in column (distribution in percentage)			
12 (70.6%)	3 (17.6%)	1 (5.9%)	1 (3.9%)
11 or more years of experience			
1. Content of studies in accordance with Atidya text (1990) (2)	Operon model	Cultivation of varieties	Ethics (2)
2. Genetic diseases (6)	Molecular genetics (6)	Genetic engineering (7)	Importance of early detection of disease
3. Determination of sex (3)	DNA replication	Dolly—the cloned sheep	Genetic consultation for families
4. Mendelian heredity (5)	Mutations (3)	The use of genetic engineering (4)	Heredity and environment
5. Sex linked (5)	Genes and the formation of characteristics (3)	Biotechnology	
6. Gene linkage (2)	Gene regulation	Methods of research	
7. Recombination	Mutagens		
8. Codomination (2)	Chromosome mapping		
9. Population genetics	Microbiology		
10. Blood types	Inhibition and activation		

Table XI. Continued

Genetics topics	Molecular genetics	Genetic engineering	Societal issues
11. Affect on heredity by alleles and multiple alleles			
12. Similarity of parents and children			
13. Mating of kin			
14. Probability			
15. Family "trees"			
16. Influence of disease on the distribution of the characteristic in the population			
No. of items in column (distribution in percentage)			
45 (52.9%)	19 (22.4%)	16 (18.8%)	5 (5.9%)

include relevant open questions on these issues in the respective textbooks chapters. Bryant (2000) students should be informed, and learn about the relationships between science, technology, and society. The opportunities of finding jobs in a highly scientific–technological oriented society depend on whether or not these subjects are made available and relevant to the students' needs and interests.

Students should realize the relevancy of the science curricula to their daily life and human needs. However, teachers and educators on all levels should provide an educational environment in which scientific knowledge will be acquired, on the basis of solid moral, ethics, and human values. Teaching in an inquiry mode integrated with the STS approach, rather then the typical expository one, and new methods of teaching only does not assure humanistic and educational results.

Another issue which should be considered was the trend of separating the instruction of science and technology in the 1960s, in the then "new science curricula." This arose primarily as a result of political and social reasons, rather emanating from a profound philosophical debate.

It is currently accepted that science and technology are mienelated, has a reciprocal influence on each other, and each contributing to the development of the other by a sequence of mutual contributions. Science and technology cannot be separated in the high school curricula and the teaching and cognitive skills involved should be firmly anchored on moral, ethical, and human values as well.

On the basis of the crimes committed in World War II by German scientists, and the possible future abuse of recent achievements in science and technology, decisions about their use should be based on ethical, moral, and human values. Therefore, instruction of science and technology should always be accompanied by opportunities in which students can relate and discuss their impact on human life.

Learning science and technology related to societal issues is one of the conditions that can free people from poverty, ignorance, and prejudice. The results of scientific research should and can be objective; if its experiments are carried out according to the conventional rules accepted by the scientific community. However, the scientific results, findings, and technological outcomes can be interpreted differently, based on the philosophical and moral values of those who make use of them, whether scientists or politicians.

We will conclude this part of our paper by relating to the following:

1. It is astonishing to find in the German Chronicles of the Identification, Prescription, and Extermination of those who were "different" (Muller-Hill, 1998, pp. 7–22) that the list of people who led to the atrocities of the World War II contains almost equal numbers of scientists in eugenics, evolution, medicine, euthanasia, and anthropologists, and Nazi politicians. It is difficult to distinguish who influenced whom to be involved in these atrocities.
2. One comes to the same conclusion in reading the last pages, of the "Name Index," pp. 233–246 (Muller-Hill, 1998). The number of German doctors who committed suicide at the end of the war, either to avoid trial or due to their feelings after their involvement in what they called "Aryan race theory"

implementation, is comparable to the list of politicians and army officers who stood trial and were executed.

The two paragraphs mentioned above raise a more vital question regarding the science education in the twenty-first century. In each chapter in classic genetics, genetic engineering, evolution and natural selection, molecular biology, medicine and technology, relevant historical events should be introduced, as occurred because of the misleading interpretations of scientific theories, or intentional misuse which entailed criminal war activities. These topics of human history should be accompanied by class discussions, in which no one dictates his/her beliefs, but all are required to take a stand on moral, ethical, and human values from a personal point of view. These issues become more acute to scientists and educators in recent times because of the demagogical manner in which poverty and religious faith are manipulated.

We must educate to understanding and respect of all believes. It is only possible to free people from ignorance, prejudice, and poverty by teaching science and technology in a STS approach, combined with social and art sciences, to provide them with a solid humanistic basis for life. Although science and technology are included in our curriculum, the third component, the societal issues, require more attention.

Science education should go a step further, so that because of the recent advances in molecular biology, genetic engineering, the human genome project, evolution, eugenics, and technologies (with their potential applications for good and bad). All these disciplines should include courses which address societal and bioethics issues, in order that future scientists understand their role and be aware of how dangerous is their impact on society. This is particularly true regarding the instruction of subjects like molecular biology, genetics engineering, medicine, and technology related applications. In their study, Don *et al.* (2003) mentioned that specific topics can serve as learning goals in which students can acquire higher cognitive skills and lead discussions on ethics and moral issues in the classroom. For example, inserting a segment of DNA that carries a characteristic trait of micro-organism into a descendant, and the cloning of a human embryo genome in order to develop a potential gene for excellence in sport. Dass (1997) also advocates for organizing high school biology experiences around bioethical issues in a STS approach. Cloning genetically modified foods, in vitro fertilization techniques, and organ transplantation are the topics for teacher's use of controversial issues in high school biology lessons since these subjects have the potential of raising moral, ethical, and social concerns according to Van Rooy (2000). Such topics can give teachers the opportunity to include in their teaching biological research of everyday relevance. They are also adequate to national science curricula requirements in the United Kingdom and Australia where students become aware of personal, ethical, and societal aspects of biology research consequences by addressing controversial issues through classrooms discussions led by their teachers.

At the college level we also have the study in which Anderson (2003) relates to the ethical issues and active involvement of students in the learning process in a course on Philosophy and Social Ethics. Bryant and Baggott la Velle (2003) emphasize the importance of awareness among biology teachers and biologists of the ethical and social implications of their work while describing a module in bioethics, targeted to students majoring in biology and science education.

This enterprise may "*lessen the chance of a recurrence of a similar misuse and perversion of science and medicine in the future*" (Muller-Hill, 1998, Translator preface, Fraser, p. xii). These recommendations can and should be applied in all the levels of formal education to all the science and technology subjects that could potentially affect human life.

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